

The 2003/2004 Superoutburst of SDSS J013701.06-091234.9

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Abstract

We report on time-resolved photometry of the superoutburst of an SU UMa-type dwarf nova, SDSS J013701.06-091234.9 in 2003 December-2004 January. The obtained light curves definitely show superhumps with a period of 0.056686 (12) d, which is one of the shortest superhump periods among those of SU UMa-type dwarf novae ever observed. Considering quiescent photometric studies, we estimated the fractional superhump excess to be 0.024. Spectroscopic observations by Szkody et al. (2003) provided evidence for TiO bands despite the short orbital period, implying that the system has a luminous secondary star. We draw a color-color diagram of SU UMa-type dwarf novae in quiescence using 2MASS archives, revealing that the location of this star in the color-color diagram is deviated from the general trend. The distance to the system was roughly estimated to be 300 ± 80 pc, using the empirical period-absolute magnitude relation and based on the proper motion.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (SDSS J013701.06-091234.9) — stars: novae, cataclysmic variables — stars: oscillations

1. Introduction

Dwarf novae are a subclass of cataclysmic variables that consist of a white dwarf primary with an accretion disk and a Roche-lobe-filling late type secondary star (for a review, see Warner 1995, Hellier 2001).

SU UMa-type stars are a subclass of dwarf novae exhibiting two types of outburst: normal outbursts lasting for a few days and superoutbursts for weeks, during which ~ 0.2 mag modulations called superhumps are always observed. Many models have been proposed in order to explain outbursting properties for SU UMa-type dwarf novae. The most promising one is the thermal-tidal instability model (for a review, see Osaki (1989)) that is also supported by observations.

Most cataclysmic variables below the period gap are believed to evolve towards short orbital periods due to gravitational-wave radiation. Minimum of the orbital period of CVs (usually referred to as *period minimum*) has been proposed to be around 65 min (Kolb, Baraffe 1999). It is expected that near the period minimum, where the

secondary begins to degenerate, the inversion of mass-radius relation causes the orbital period to become longer with evolution. Some authors claim that WZ Sge-type dwarf novae, which is a subtype of SU UMa-type dwarf novae, may have experienced the inversion (Patterson et al. 2005). It is widely accepted that the most of CVs below the period gap continue the above mentioned standard evolutionary sequence.

Recently, theory predicts another evolutionary sequence for CVs (Baraffe, Kolb 2000, Podsiadlowski et al. 2003). Given a certain range of mass for the primary and the secondary, the secondary does not become fully convective in its interior, which leads the secondary to have perpetual magnetic braking even below the period gap. As a consequence, the orbital period can become shorter than even the theoretical period minimum. AM CVn stars (Nelemans 2005), whose orbital periods are less than 60 min, are the most promising systems that experienced the aforementioned scenario. EI Psc (= 1RXS J232953.9+062814, Wei et al. 2001, Uemura et al. 2002, Thorstensen et al. 2002a, Skillman et al. 2002, Zhou,

Table 2. List of observers.

code	site	telescopes	CCD
njh	Mie, Japan	25cm	CV-04
kyo	Kyoto, Japan	30cm	ST-7E
BM	Pretria, South Africa	30cm	ST-7E
kis	Tsukuba, Japan	30cm	ST-8E
gets	Gunma, Japan	25cm	AP-7E
mhh	Saitama, Japan	20cm	ST-7E
DRS	Indiana, USA	36cm	ST-10XME
AO	Nyrola, Finland	25cm	ST-8E

Qiu 2002) and V485 Cen (Olech 1997) may be possible candidates for the progenitor of AM CVn stars.

SDSS J013701.06-091234.9 (hereafter J0137) was first identified as a cataclysmic variable by Szkody et al. (2003). Optical spectroscopy for J0137 showed double-peaked H α profiles, as well as TiO bands. Radial velocity studies exhibited a periodicity of 84 min.

An eruption of J0137 had been only recorded by the All Sky Automated Survey (Pojmanski 2002) as ASAS 013701-0912.6 until the 2003 December outburst was caught. The first recorded data showed that the object brightened up to 12.6 in *V* band on 2001 May 27, then gradually faded down to 13.4 on June 9, 2001, and finally became below the detection limit on June 20, 2001. As inferred from the duration of the brightening, the recorded brightening strongly suggested a superoutburst of SU UMa-type dwarf novae.

During quiescent photometric observations of J0137, Pretorius et al. (2004) serendipitously discovered a brightening of the object up to $V = 12.5$ mag on Dec. 21, 2003, when light curves showed superhumps with an amplitude of 0.2 mag, confirming J0137 as an SU UMa-type dwarf nova.

2. Observations

CCD photometric observations were performed by the VSNET Collaboration Team (Kato et al. 2004b). Table 1 demonstrates log of observations. Used telescopes, CCDs and sites are listed in Table 2.

The Kyoto team used a Java-based point spread function (PSF) photometry package developed by one of the authors (TK) after dark-subtraction and flat-fielding. Other observers performed aperture photometry mainly using AIP4WIN and IRAF package. All CCD systems listed in Table 1 are close to Kron-Cousins R_C band. The magnitudes of each site were adjusted to the Tsukuba system in which the differential magnitudes of the variable were measured using TYC2-5277.0337.1 as a comparison star, whose constancy during the run was used nearby check stars.

Heliocentric corrections to the observation times were applied before the following analysis.

3. Results

3.1. Light curve

Figure 1 represents the obtained light curve of the 2003-2004 superoutburst of J0137. Quiescent photometric observations for the variable were performed by Pretorius et al. (2004) on HJD 2452989 and HJD 2452990, when the object was as faint as $V = 18.6$ (Pretorius et al. 2004). Then Pretorius et al. (2004) serendipitously detected the outburst of the object at HJD 2452995.29032, with a magnitude of $V = 12.5$. ASAS-3 system also detected the eruption of the object at HJD 2452993.67590 with a magnitude of $V = 12.8$, while on HJD 2452991.64767 the magnitude was below the detection limit. Thus the time of the maximum brightness is restricted to be on HJD 2452994 or HJD 2452995.

The plateau stage of the superoutburst lasted more than 2 weeks. The value is slightly longer than that of ordinary SU UMa-type dwarf novae. Combined the duration of the plateau stage with the fact that the amplitude of J0137 exceeded 6 mag, the object is within the framework of large-amplitude SU UMa-type dwarf novae (TOADs, Howell et al. 1995). The mean decline rate during the plateau stage was about 0.08 mag d^{-1} . A rebrightening¹ feature is clearly shown on HJD 2453018, which is often observed in WZ Sge-type dwarf novae and SU UMa-type dwarf novae with short superhump periods. This implies that J0137 has some relation with these systems.

We performed a period search of the object during the plateau stage of the superoutburst after subtracting the linear declining trend. Figure 2 shows the theta diagram using PDM method (Stellingwerf 1978), which indicates 0.056698 (10) days is the best-estimated superhump period. It should be noted that the obtained superhump period is comparable to that of WZ Sge-type dwarf novae, AL Com (0.05722 d, Nogami et al. 1997), HV Vir (0.05820 d, Ishioka et al. 2003), and WZ Sge itself (0.05721 d, Patterson et al. 2002).

3.2. Superhumps

The mean superhump profile during the plateau stage is shown in figure 3. A rapid rise and slow decline is typical of that of SU UMa-type dwarf novae. Figure 4 shows the daily evolution of superhumps during the plateau stage. Each light curve is folded by the superhump period of 0.056698 d.

We also investigated the existence of early superhumps on HJD 2452996. Early superhumps, having a double-peaked profile and a period almost the same as their orbital period, are characteristic of WZ Sge-type dwarf novae (Osaki, Meyer 2002, Kato 2002, Patterson et al. 2002)². As can be seen in the top-left panel of figure 4, the superhumps had already developed on HJD 2452996, which is in agreement with the observations by

¹ Some authors use the term “echo outburst”.

² Early superhumps are also called orbital humps (Patterson et al. 2002) or early humps (Osaki, Meyer 2002). The difference among these authors is originated from their interpretation of physical process near the bright maximum.

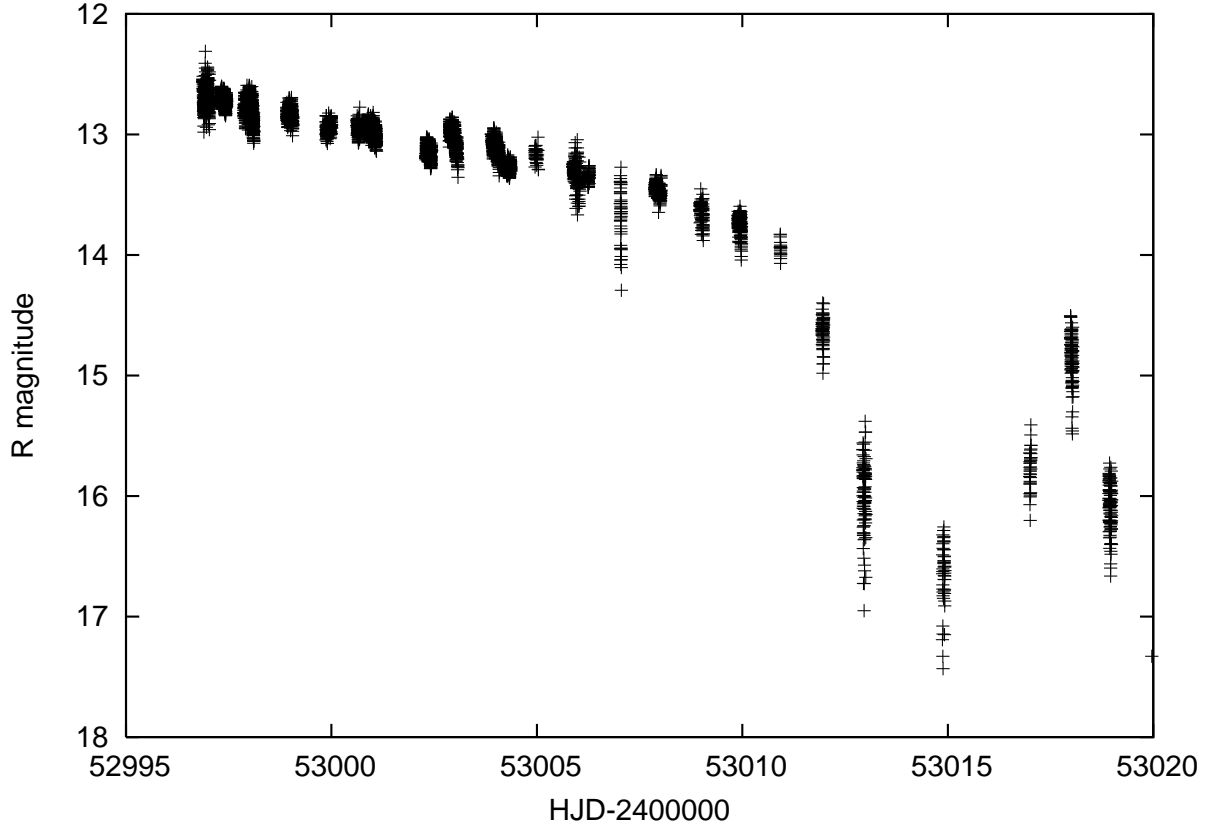


Fig. 1. The resulting light curve of SDSS J0137. The abscissa and the ordinate mean the heliocentric Julian day and the magnitude close to R , respectively. A rebrightening could be seen around HJD 2453018.

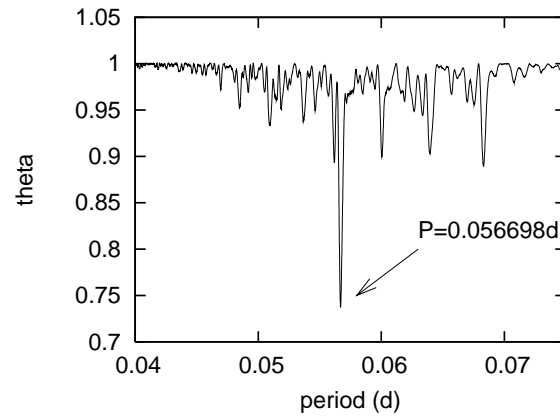


Fig. 2. Results of a period analysis by applying the PDM method to the data during the plateau stage. The abscissa and the ordinate denote periods in the unit of day and theta, respectively. After subtracting linear decline trend of the light curve, we determined $P = 0.056698$ days as the best-estimated period of superhumps. The second peak close to the above derived period seems to be alias. However, we cannot exclude the possibility of a real periodicity.

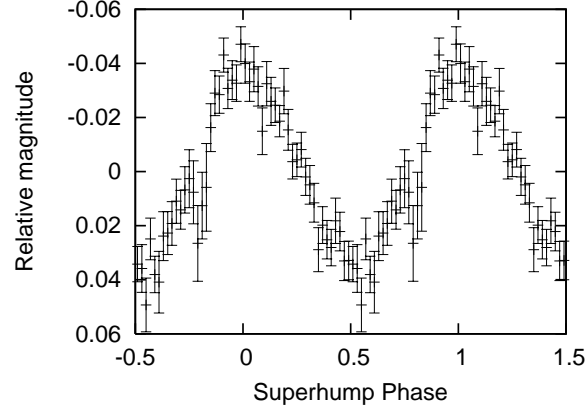


Fig. 3. Phase-averaged daily light curves of superhumps during the plateau stage, after folded by $P=0.056698$ days. The vertical and the horizontal axis denote the relative magnitude and phase, respectively.

Fig. 4. Phase-averaged light curve of superhumps in SDSS J013701.06-091234.9, covering between HJD 2452996 and HJD 2453007, folded by 0.056698 d. The vertical and the horizontal axes denote the relative magnitude and the phase, respectively. A rapid rise and slower decline, which is a typical feature of superhumps, are shown during the early stage of observations.

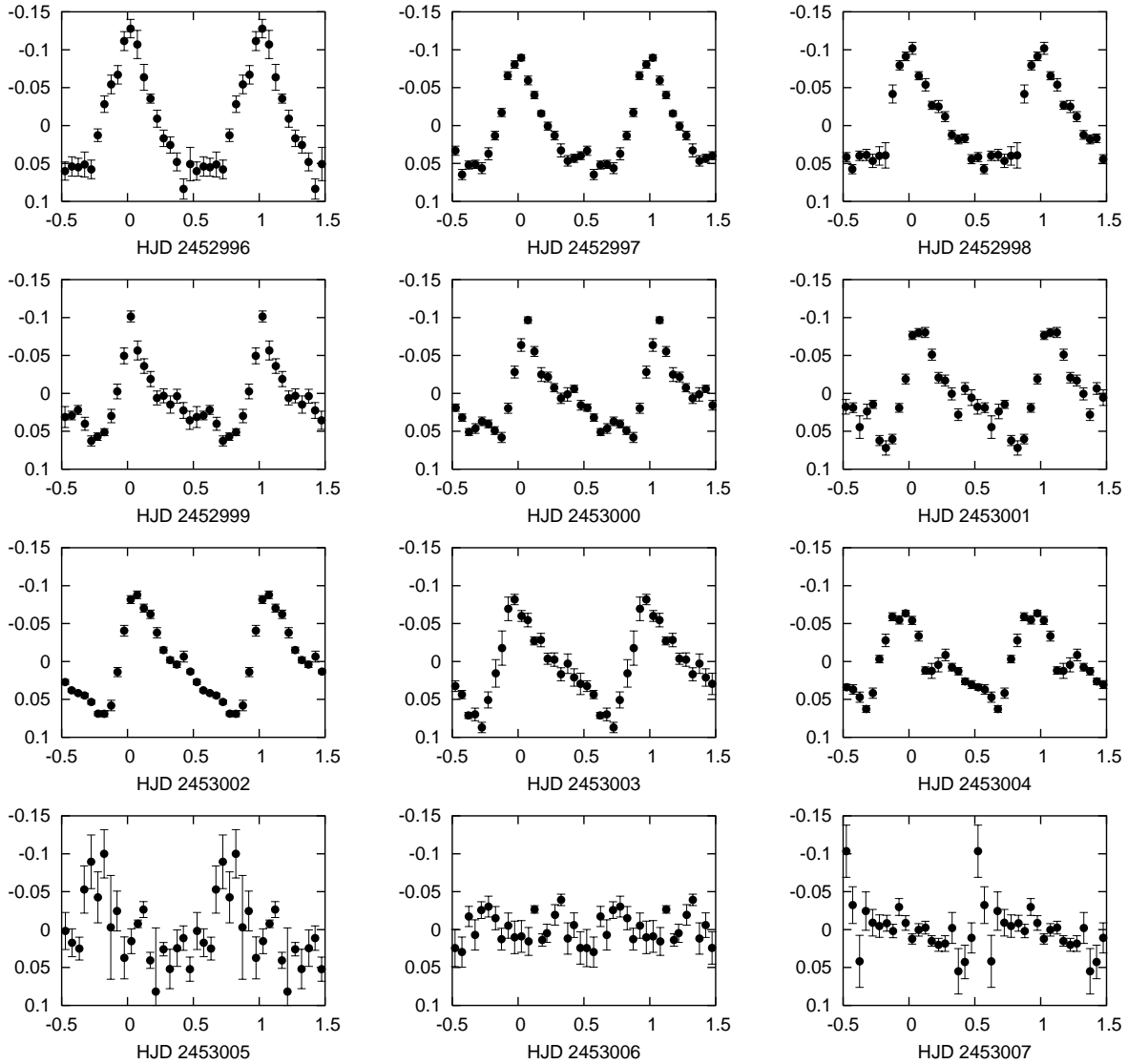


Table 1. Journal of observations.

Date	HJD(start)*	HJD(end)	N [†]	Exp(s) [‡]	Code/ <i>S</i>
23 Dec,2003	52996.86904	52996.98490	151	30	njh
	52996.88505	52997.03497	327	30	kyo
	52997.29186	52997.44838	444	28	BM
24 Dec,2003	52997.86596	52997.98659	159	30	njh
	52997.93928	52998.10752	360	30	kis
	52997.98697	52998.11349	203	30	gets
25 Dec,2003	52998.91343	52999.05886	303	30	kis
26 Dec,2003	52999.86686	53000.00316	176	30	njh
27 Dec,2003	53000.88082	53001.08705	418	30	kis
	53000.96131	53001.09511	225	40	mhh
	53000.61786	53000.69084	100	45	DRS
28 Dec,2003	53002.29974	53002.43352	375	28	BM
29 Dec,2003	53002.87155	53003.07811	359	30	gets
30 Dec,2003	53003.89347	53004.08564	322	30	gets
	53004.25485	53004.36336	308	28	BM
	53004.95170	53005.03557	40	30	gets
1 Jan,2004	53005.88064	53006.05076	176	30	gets
	53006.23946	53006.27625	48	60	AO
2 Jan,2004	53006.95027	53007.05426	168	30	gets
	53007.03134	53007.05456	47	30	kis
3 Jan,2004	53007.87306	53008.02304	241	30	gets
4 Jan,2004	53008.96772	53009.04763	76	30	kis
5 Jan,2004	53009.89337	53009.91637	42	30	gets
	53009.92619	53009.97811	105	30	kis
	53010.92457	53010.93495	18	30	kis
7 Jan,2004	53011.93861	53011.97924	65	30	kis
8 Jan,2004	53012.93191	53013.00878	96	30	kis
10 Jan,2004	53014.87110	53014.93196	48	30	gets
12 Jan,2004	53016.98983	53017.02530	37	30	gets
13 Jan,2004	53017.98725	53018.04615	92	30	kis
14 Jan,2004	53018.92030	53018.98921	105	30	kis
15 Jan,2004	53019.96453	-	1	30	kis

* HJD-2400000, [†] Number of frames[‡] Exposure times[§] observer's code. (see Table 3.2)

Pretorius et al. (2004). However, we cannot exclude the possibility that early superhumps did emerge near the maximum, and disappeared before our observations.

3.3. Superhump period change

The maximum timings of superhumps measured by eye are listed in Table 3. The typical error is an order of 0.001 d for each maximum. A cycle count *E* is set to -7 at the first detected maximum, corresponding to HJD 2452996.9277. A linear regression of the superhump maximum timings yielded the following equation:

$$HJD(max) = 2452997.3248(9) + 0.056686(12) \times E \quad (1)$$

The obtained *O*–*C* diagram is demonstrated in figure 6, where the dashed line denotes the beginning of late superhumps discussed in Pretorius et al. (2004). The data can be apparently fitted by a quadratic function. However, considering the argument by Pretorius et al. (2004), in which they have enough data to explore superhump period changes during the later stage of the outburst, the break

in Figure 6 is caused by a sudden jump of phase as seen in some SU UMa-type dwarf novae. Thus we conclude that, except the phase change on HJD 2453007, presumably due to late superhumps, there were almost no changes in superhump periods during the present superoutburst.

4. Discussion

4.1. outburst properties

The overall light curves provided firm evidence of superhumps, which allows us to identify the object as a new SU UMa-type dwarf nova. The obtained superhump period is 0.056686 (12) d, one of the shortest superhump periods among SU UMa-type dwarf novae ever known. The plateau stage lasted more than 2 weeks, and a rebrightening took place at least once after the termination of the plateau stage. The amplitude of the object exceeded 6 mag, and the light curve of J0137 has similarity to that of the 1998 superoutburst of WX Cet (Kato

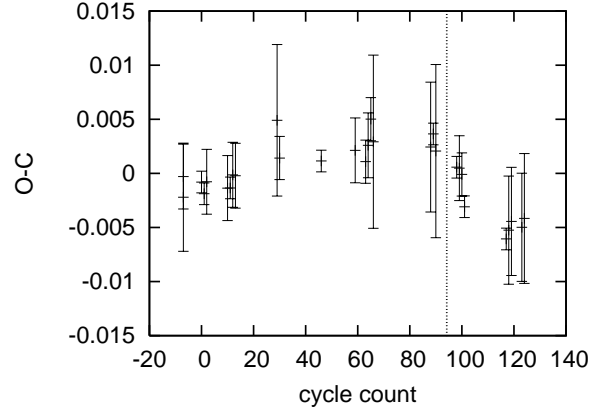


Fig. 5. $O - C$ diagram of the superhump maximum timings of J0137 during the superoutburst. A calculation is performed based on the equation (3). The vertical and the horizontal axes denote $O - C$ and the cycle count, respectively. We set $E = 0$ to HJD 2452996.9277. Note almost no changes of the superhump period till HJD 2453002. The dotted line indicates the beginning of late superhumps suggested by Pretorius et al. (2004).

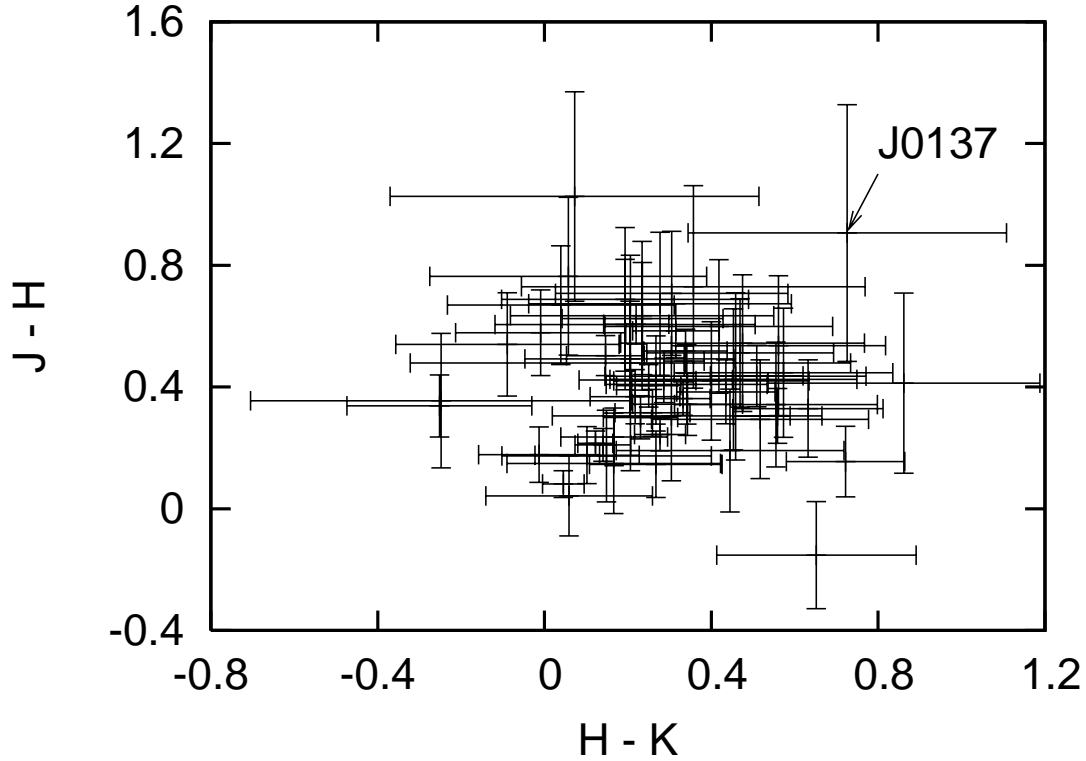


Fig. 6. Near-infrared color-color diagram of SU UMa-type stars listed on Table 3. Some listed stars including ER UMa stars are suspected to be observed during outbursts. Such stars for which we cannot evaluate typical errors, are precluded. An extinction correction is not operated because most of SU UMa-type dwarf novae are not distant and the effect is marginal. Note that the location of J0137 is far from that of other stars, suggesting the peculiar nature of the object.

Table 3. Timings of superhump maxima.

E	HJD max	error [†]
-7	52996.9277	0.003
0	52997.3240	0.001
1	52997.3796	0.001
2	52997.4374	0.003
10	52997.8903	0.003
11	52997.9470	0.001
12	52998.0049	0.003
13	52998.0615	0.003
29	52998.9736	0.007
30	52999.0268	0.002
46	52999.9335	0.001
59	53000.6714	0.003
63	53000.8971	0.002
64	53000.9553	0.003
65	53001.0144	0.002
66	53001.0690	0.008
88	53002.3156	0.006
89	53002.3735	0.001
90	53002.4286	0.008
98	53002.8806	0.001
99	53002.9372	0.003
100	53002.9933	0.002
101	53003.0470	0.001
117	53003.9510	0.001
118	53004.0085	0.005
119	53004.0660	0.005
123	53004.2922	0.005
124	53004.3497	0.006

[†] unit in day.

et al. 2001a) and that of 1996 superoutburst of SW UMa (Nogami et al. 1998) in terms of the decline rate, a duration of the plateau stage, and an outburst amplitude. This certifies J0137 as a large amplitude SU UMa-type dwarf nova (TOADs, Howell et al. 1995).

4.2. superhump period changes

It had been considered that superhump periods of SU UMa-type dwarf novae decrease with time. However, since the 1995 superoutburst of AL Com, some objects have been confirmed to increase the superhump period with time. Such systems include AL Com (Nogami et al. 1997), V485 Cen (Olech 1997), EG Cnc (Patterson et al. 1998, Kato et al. 2004a), SW UMa (Semeniuk et al. 1997; Nogami et al. 1998), V1028 Cyg (Baba et al. 2000), WX Cet (Kato et al. 2001a), HV Vir (Kato et al. 2001b; Ishioka et al. 2003), RZ Leo (Ishioka et al. 2001), V592 Cas (Kato, Starkey 2002), WZ Sge (Patterson et al. 2002), EI Psc (Uemura et al. 2002), V1141 Aql (Olech 2003), KS UMa (Olech et al. 2003), VW CrB (Nogami et al. 2004b), TV Crv (Uemura et al. 2005), GO Com (Imada et al. 2005), and ASAS 002511+121712 (Imada et al. in prep.)³. A decrease of superhump period was interpreted as being due

³ It also should be noted that TT Boo shows both decrease and increase of superhump periods (Olech et al. 2004).

to shrinkage of the disk radius, or a natural consequence of mass depletion from the disk (Osaki 1985). Most of SU UMa-type dwarf novae having orbital periods below 0.063 d tend to increase the superhump period as time elapses (Imada et al. 2005).

J0137, having the orbital period of 0.0553 d, is expected to be a dwarf nova with positive derivative of the superhump period. However, our results clearly indicate that the superhump period hardly changed during the first half of the plateau stage. Kato et al. (2001b) suggested that the period increase may be correlated to a low mass ratio and/or a low mass transfer rate, which is supported by recent observations (Nogami et al. 2003). However, EI Psc and RZ Leo obviously violate the Kato's suggestion (Uemura et al. 2002; Ishioka et al. 2001); spectroscopic observations have revealed a relatively high mass transfer rate and a high mass ratio of these objects.

Recently, Uemura et al. (2005) discovered that an SU UMa-type dwarf nova, TV Crv exhibits two types of the superhump period change: positive $P_{\dot{\text{dot}}} = \dot{P}_{\text{sh}}/P_{\text{sh}}$ during the 2001 superoutburst without a precursor and almost no changes $P_{\dot{\text{dot}}}$ during the 2004 superoutburst with a precursor. Uemura et al. (2005) suggests that this difference mainly depends on the disk radius before a superoutburst is triggered. At the beginning of an outburst, if the accretion disk has large masses beyond the 3:1 resonance radius at which an eccentric mode originates, the mode sufficiently propagates outward because of the plenty matter beyond the 3:1 resonance radius, so that the outer region of the accretion disk becomes more eccentric, leading to the positive $P_{\dot{\text{dot}}}$.

J0137, when based on the arguments by Uemura et al. (2005), was likely to have insufficient mass at the ignition of the outburst. As a consequence, an eccentric mode could not propagate so far as other SU UMa-type dwarf novae exhibiting positive $P_{\dot{\text{dot}}}$. The validity of Uemura's arguments should be explored in the future observations for SU UMa-type dwarf novae with short orbital periods, and should be tested by hydrodynamical simulations.

4.3. distance

If the orbital period of the system and the maximum V magnitude of a normal outburst are known, one can roughly estimate the distance to the object. In this subsection, we try to estimate the distance to J0137 in the same manner as that used by Kato et al. (2003), Nogami et al. (2004a), and Nogami et al. (2004b).

An empirical relation derived by Warner (1987) is that the absolute V magnitude at the maximum is the function of the orbital period of the object, that is,

$$M_V = 5.64 - 0.259P, \quad (2)$$

where P is the orbital period in the unit of hour. This relation, however, can adapt only to a low inclination system, at most, to an intermediate inclination system. In the case of J0137, we need caution to use the equation (2). First, although equation (2) should be used to the maximum magnitude of a normal outburst of SU UMa stars, a

normal outburst has not been observed for J0137. Second, spectroscopic observations of J0137 (Szkody et al. 2003) shows doubly-peaked profile of $H\alpha$, implying an intermediate or high inclination. For the first caution, we used that the magnitude of a normal outburst is 0.5 ± 0.5 mag fainter than that of a superoutburst. For the second caution, the absence of an eclipse can rule out the possibility of a high inclination system of J0137. Thus, substituting 1.3283 (hr) into P, we obtain $M_V \sim 5.3$. Assuming the maximum magnitude of a normal outburst to be 12.7 ± 0.5 , we roughly derived 300 ± 80 pc as a likely distance.

We further estimated a distance to J0137 from its proper motion. The proper motion of J0137 is listed in the USNO B1.0 catalog as $(\mu_{RA}, \mu_{Dec}) = (-36, -50)$ in the unit of mas. Supposing the transverse velocity to be 100 km/s (Thorstensen 2003), the distance to J0137 is estimated to be about 320 pc, which does not contradict that derived above.

4.4. Secondary star

SU UMa stars with short orbital periods, including WZ Sge stars, show almost no evidence for the secondary star in the optical spectrum (e.g., Howell, Ciardi 2001). A quiescent spectrum of J0137, however, clearly exhibits TiO bands around 7000 Å (Szkody et al. 2003), suggesting that a contribution of the M-type secondary is significant even in the optical range. This implies a peculiar nature of the object when taking into account the orbital period of J0137 is close to the theoretical period minimum.

In order to quantitatively investigate secondary stars in SU UMa stars, we extracted infrared magnitudes of SU UMa stars from the 2MASS catalog (Table 4) (cf. Hoard et al. 2002). These magnitudes could reflect on the secondary star of each system. All of stars listed in Table 4 are within 5 arcsec from the coordinates listed in Downes et al. (2001). Using this table, we obtained the color-color diagram of Figure 7. In this figure, ER UMa stars and SU UMa stars which could be measured during outbursts are precluded. Note that the location of J0137 is slightly away from the general trend. This star seems to be “reddest”, and the colors of $J - H$ and $H - K$ of J0137 is consistent with those of late M-type to L-type stars, or post-AGB stars (Dahn 2002). This may mean that the secondary star of J0137 is later than that of other SU UMa stars. In conjunction with the spectroscopic observations, we propose that there is an evolved and luminous secondary star in J0137 like EI Psc and V485 Cen⁴. The exact spectrum type of the secondary star should be confirmed in the future observations.

4.5. evolutionary sequence

As mentioned above, not only theoretical works (Podsiadlowski et al. 2003) but also observations (Uemura et al. 2002; Olech 1997) have proposed an evolutionary se-

quence of binary stars that evolve to AM CVn-type stars. Kato (2004) suggested that an SU UMa-type dwarf nova LL And has experienced an intermediate evolution between AM CVn-type stars and the bulk of CVs, judging from an unexpectedly large superhump excess of 3.5%.

J0137 has a superhump excess of 2.4%. Although the value is smaller than that of LL And, it is larger than that of SW UMa (2.1%, Semeniuk et al. 1997, Nogami et al. 1998) and WX Cet (1.8%, Kato et al. 2001a) despite their longer orbital periods than that of J0137. Thus, in conjunction with the peculiar properties of the secondary star, we suggest that an evolutionary sequence of J0137 is slightly deviated from the most of CVs’ evolution as proposed by Kato (2004) for LL And.

5. Conclusions

Photometric observations of the superoutburst of J0137 from December 2003 to January 2004 revealed that (1) the mean superhump period is 0.056686 (12) d, which is one of the shortest superhump periods among SU UMa-type dwarf novae, (2) the amplitude of J0137 during the superoutburst exceeded 6 mag and the plateau stage of J0137 lasted about 2 weeks, which confirmed J0137 to be a new member of SU UMa-type dwarf novae with a large amplitude, (3) the changes of superhump period were hardly observed during the plateau stage, but a signature of late superhumps appeared, (4) a distance to J0137 is roughly estimated to be 320 ± 80 pc, based on the measured proper motion for the object and an empirical relation given by Warner (1987), (5) based on the 2 MASS observations, the secondary star of J0137 has much later spectral type than that of other SU UMa-type dwarf novae, and (6) the fractional superhump excess of J0137 is a large value of 0.024 for its short orbital period, suggesting that an evolutionary sequence of J0137 may be slightly deviated from that of standard CVs. This implies that J0137 places a missing link between ordinary SU UMa stars and a progenitor for AM CVn stars.

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⁴ However, EI Psc in Figure 7 is located in the general trend, despite detection of the secondary star in the optical range. Spectroscopic observations also favor a K-type secondary star in EI Psc (Hu et al. 1998). The reason for the difference between EI Psc and J0137 is left as an open problem.

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Table 4. J, H, and K magnitudes of SU UMa stars in the 2MASS catalog.

Object [§]	Offset	Period	Jmag (err)	Hmag (err)	Kmag (err)	Type	Remark*
El Psc	1.546	0.044567	14.684(43)	14.316(46)	14.099(62)	SU	-
GW Lib	1.588	0.05332	16.191(88)	15.586(126)	15.393(186)	WZ?	-
BW Scl	3.029	0.054323	15.835(83)	15.493(122)	14.938(121)	WZ?	-
DI UMa	0.640	0.054564	15.532(59)	15.262(109)	15.126(142)	ER	-
V844 Her	1.451	0.05464	16.763(150)	16.284(204)	16.078(324)	SU	-
J0137 ¹	0.700	0.05535	16.928(224)	16.022(198)	15.296(184)	SU	-
J1238 ²	0.118	0.05592	16.651(139)	16.490(238)	16.424	SU?	-
HS 2331 ³	2.335	0.056309	15.528(67)	15.199(93)	14.567(87)	SU	-
PU CMa	1.097	0.05669	12.486(24)	12.461(24)	12.389(24)	SU	1, 2
WZ Sge	0.707	0.05669	14.862(41)	14.557(49)	13.998(57)	WZ	-
SW UMa	0.474	0.05682	15.621(67)	15.327(128)	14.810(132)	SU	-
J0532 ⁴	0.924	0.057	15.175(41)	15.020(75)	14.298(67)	SU	-
ASAS 0025 ⁵	0.387	0.05707	16.663(138)	15.934(195)	15.577(217)	WZ?	2
CC Scl	2.458	0.0587	16.040(72)	15.849(130)	15.404(143)	SU?	-
KV Dra	0.585	0.05876	16.674(133)	16.170(255)	17.118	SU	-
T Leo	2.385	0.05882	14.771(43)	14.335(58)	13.826(53)	SU	-
HS 2219 ⁶	0.090	0.0599	15.976(92)	15.440(138)	14.879(119)	SU	-
V1040 Cen	3.244	0.0603	16.295(126)	15.791(149)	15.707	SU	-
AQ Eri	1.179	0.06094	16.425(121)	15.661(138)	15.604(194)	SU	-
MM Sco	4.856	0.06136	16.432(151)	15.651(141)	16.488	SU	-
RX Vol	1.461	0.06117	16.527(131)	16.165(202)	15.185	SU	2
V4140 Sgr	0.963	0.06143	16.637(126)	16.700	15.903	SU	-
V1159 Ori	0.929	0.062178	13.817(27)	13.781(46)	13.675(50)	ER	-
V2051 Oph	0.917	0.062428	14.327(33)	13.872(43)	13.530(39)	SU	1
BC UMa	0.467	0.06261	16.785(142)	16.351(245)	15.559	SU	-
EK TrA	0.760	0.06288	16.490(148)	16.077(148)	15.215(178)	SU	-
OY Car	1.855	0.06312	14.953(37)	14.435(35)	14.097(65)	SU	-
ER UMa	1.004	0.06366	13.606(28)	13.454(33)	13.495(37)	ER	-
CG CMa	2.444	0.0636	15.276(45)	14.938(57)	15.190(165)	SU?	2
V436 Cen	0.993	0.06383	14.220(28)	13.858(27)	13.526(38)	SU	2
VY Aqr	0.863	0.06450	15.278(52)	14.855(93)	14.588(91)	SU	2
UV Per	0.488	0.06490	16.468	15.726(147)	15.431(188)	SU	-
AK Cnc	0.735	0.0651	13.772(28)	13.755(39)	13.716(43)	SU	1
IX Dra	0.418	0.06646	16.470(120)	16.289(224)	16.003	ER	-
SX LMi	0.038	0.06720	15.707(62)	15.558(103)	15.392(153)	SU	-
SS UMi	0.454	0.06778	15.874(92)	15.519(129)	15.767(328)	SU	-
CY UMa	0.733	0.06795	16.012(67)	15.500(111)	15.031(113)	SU	-
BZ UMa	0.511	0.06799	14.824(43)	14.440(62)	14.005(56)	SU	-
KS UMa	1.657	0.06800	16.087(95)	15.640(117)	15.067(145)	SU	-
RZ Sge	0.741	0.06828	15.734(87)	15.314(108)	14.914(126)	SU	-
TY Psc	0.661	0.06833	13.226(21)	13.145(23)	13.100(27)	SU	-
IR Gem	1.370	0.06840	15.218(41)	14.875(61)	14.532(71)	SU	-
V550 Cyg	1.403	0.0689	14.592(50)	14.166(61)	13.984(69)	SU	1, 2
V1504 Cyg	0.275	0.06951	16.110(89)	15.912(154)	15.402	SU	-
FO And	0.347	0.07161	15.493(51)	15.646(125)	14.994(114)	SU	-
VZ Pyx	0.731	0.07332	14.186(33)	13.871(44)	13.612(46)	SU	-
CC Cnc	0.302	0.07352	16.517(120)	16.082(155)	15.624(158)	SU	-
HT Cas	1.194	0.073647	14.703(31)	14.226(40)	13.843(55)	SU	1
IY UMa	1.255	0.07391	15.725(92)	15.100(92)	14.865(101)	SU	-
J1556 ⁷	3.487	0.07408	16.285(106)	15.741(119)	15.266(173)	SU	-
VW Hyi	0.311	0.07427	12.522(24)	12.037(26)	11.702(22)	SU	-
Z Cha	1.616	0.074499	13.968(35)	13.564(35)	13.314(42)	SU	-
QW Ser	0.171	0.07457	16.274(96)	15.949(157)	15.392	SU	-
NSV 10934	0.858	0.07478	14.442(41)	14.206(54)	14.039(74)	SU	2
WX Hyi	1.250	0.07481	13.482(26)	13.238(28)	12.961(33)	SU	-

Table 4. (Continued)

Object [§]	Offset	Period	Jmag (err)	Hmag (err)	Kmag (err)	Type	Remark*
RZ Leo	0.777	0.07604	16.338(116)	15.664(119)	15.387(196)	WZ	-
SU UMa	0.464	0.07635	11.777(22)	11.731(23)	11.670(21)	SU	1
J1730 ⁸	2.681	0.07653	15.284(47)	15.189(89)	15.217(177)	SU	1
HS Vir	0.859	0.07690	15.016(41)	14.870(68)	14.603(91)	SU	-
V503 Cyg	2.531	0.0777	16.370(132)	15.287	15.200	SU	-
V660 Her	1.007	0.07826	14.386(35)	14.395(53)	14.448(106)	SU	1
CU Vel	1.990	0.07850	14.492(32)	13.989(34)	13.843(59)	SU	-
V630 Cyg	0.594	0.07890	14.679(38)	14.503(56)	14.401(69)	SU	-
J2100 ⁹	0.086	0.079	16.100(69)	16.411(188)	15.907	SU	-
V1113 Cyg	1.074	0.0792	15.777(80)	15.971(219)	15.070	SU	2
BR Lup	1.624	0.07950	15.179(54)	15.137(77)	15.078(123)	SU	-
DH Aql	0.853	0.08003	15.932(86)	15.263(109)	15.224(163)	SU	2
J0549 ¹⁰	0.405	0.08022	15.619(50)	15.210(81)	14.869(112)	SU?	-
PV Per	0.563	0.0805	15.181(38)	15.145(71)	14.952(114)	SU	1, 2
TU Crt	0.933	0.08209	16.225(104)	15.517(100)	15.212(179)	SU	-
RX Cha	0.292	0.0839	16.765(151)	16.270(182)	15.339	SU	2
TY PsA	1.161	0.0841	14.290(30)	13.869(43)	13.583(34)	SU	-
V877 Ara	0.555	0.08411	16.076(97)	15.617(135)	16.181	SU	2
J2234 ¹¹	0.278	0.085	16.449(92)	16.024(140)	15.571(156)	SU?	-
HV Aur	0.870	0.08556	13.665(23)	13.455(31)	13.315(36)	SU	-
DV UMa	0.181	0.08585	16.894(172)	15.868(172)	15.796(270)	SU	-
YZ Cnc	0.359	0.08680	13.166(21)	12.951(19)	12.829(23)	SU	-
IR Com	0.293	0.087039	15.032(41)	14.611(53)	14.582(86)	SU?	1
V344 Lyr	0.595	0.08760	15.605(51)	15.432(100)	15.283(151)	SU	-
BF Ara	0.677	0.08797	14.788(33)	14.610(58)	14.623(87)	SU	2
V452 Cas	0.591	0.08810	15.908(75)	15.603(138)	15.299(147)	SU	2
GX Cas	1.197	0.09297	16.226(101)	15.538(135)	15.345(161)	SU	2
MN Dra	0.410	0.10424	16.140(91)	15.782(153)	15.433	SU	-
TU Men	0.467	0.11720	14.747(40)	14.163(49)	13.848(55)	SU	-
V478 Her	0.442	0.12	16.047(77)	15.555(113)	15.350(139)	SU?	-
VW Vul	0.348	0.1687	13.524(26)	13.274(29)	13.168(32)	SU?	1
ES Dra	0.103	0.179	15.458(64)	14.880(77)	14.889(127)	SU?	-
FS And	0.589	-	15.910(66)	15.684(119)	15.340(167)	SU?	1
BZ Cir	1.261	-	15.612(81)	15.072(89)	15.161(179)	SU	-
V699 Oph	0.433	-	14.176(32)	13.570(33)	13.350(45)	SU	-
V823 Cyg	0.286	-	15.038(59)	14.967(98)	14.742	SU	1
QY Per	0.841	-	15.347(45)	15.425(106)	15.261(127)	SU	1
V2527 Oph	2.899	-	13.699(42)	13.075(45)	12.881(43)	SU	1
V405 Vul	0.699	-	14.531(44)	14.079(47)	13.883(49)	SU	1
EF Peg	2.151	-	12.921	15.154(267)	12.607	SU	-
NSV 907	1.141	-	16.551(104)	15.917(140)	15.683(176)	SU	-
J2258 ¹²	2.629	-	14.288(34)	13.988(37)	13.758(52)	SU	-

§: ¹SDSS J013701.06-091234.9, ²SDSS J123813.73-033933.0, ³HS 2331+3905

⁴1RXS J053234+624755, ⁵ASAS 002511+1217.2, ⁶HS 2219+1824

⁷SDSS J155644.24-000950.2, ⁸SDSS J173008.38+624754.7, ⁹SDSS J210014.12+004446.0

¹⁰CTCV J0549-4921, ¹¹SDSS J223439.93+004127.2, ¹²SDSS J225831.18-094931.7

*1: Photometries may be carried out during outbursts.

2: Orbital periods have not been measured. Instead, superhump periods are represented.